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LIVING AND QUATERNARY OSTRACODA FROM THE EASTERN ADRIATIC SEA: BIOCOENOSES, THANATOCOENOSES OR PALAEOTHANATOCOENOSES?

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Many new ostracod species from the Northern Adriatic Sea are based on descriptions of empty valves that were nevertheless interpreted as being parts of recent marine habitats and listed in several zoological checklists and databases. Sedimentary-geological studies contradict this interpretation. Ostracods from 2 cores taken off the Istrian Coast prove the existence of a relatively uniform subsurface layer with a rich death assemblage from a palaeoenvironmental depth zone prior or equal to the sea-level that existed 7–5 ka BP, related to the postglacial sea-level change. This layer was covered by patches with extremely different ostracod bio-, thanato- or palaeothanatocoenoses, depending on storm re-deposition, lag deposition or bioturbation. In terms of sequence stratigraphy, the Maximum Flooding Surface and a condensed Highstand Systems Tract are still forming the bottom areas more than 5 km off the Istrian Coast.

Key words: Ostracoda, Crustacea, biocoenosis, thanatocoenosis, palaeothanatocoenosis, Quaternary, type locality, Adriatic Sea

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Mnogo novih vrsta ostrakoda iz sjevernog Jadrana opisano je na temelju praznih ljuštura. Bez obzira na to, vrste su interpretirane kao dio recentnih morskih staništa i navedene u nekoliko zooloških popisa vrsta i baza podataka. Sediment iz geoloških istraživanja proturječi ovakvoj interpretaciji. Ostrakodi iz dviju jezgri izvađenih blizu obale Istre dokazuju postojanje relativno jednoličnog potpovršinskog sloja s bogatom zajednicom mrtvih organizama, iz paleookolišne dubinske zone ispod ili u razini razine mora, koja je nastala prije 7–5 ka BP zbog postglacijalne promjene razine mora. Taj sloj bio je pokriven dijelovima izrazito raznolikih ostrakodnih bio-, tanato- ili paleotanatocenoza, ovisno o njihovoj preraspodjeli zbog djelovanja oluja, zaostalih taloženja ili bioturbaciji. Što se tiče sekvencijalne stratigrafije, Površina maksimalnog preplavljivanja (MFS) i kondenzirani Trakt visoke razine (HST) još uvijek se stvaraju na dnima udaljenim više od 5 km od obale Istre.

Ključne riječi: Ostracoda, Crustacea, biocenoza, tanatocenoza, paleotanatocenoza, kvartar, tipski lokalitet, Jadransko more

INTRODUCTION

In the years between 1960 and 1980, marine ostracods from the present-day sea floor of the Adriatic Sea were examined mainly from the Italian coast and the international

* extended version of a presentation held at the EOM 8 in Tartu, Estonia (Uffenorde, 2015)

offshore areas from (Ascoli, 1965; Masoli, 1968, 1969; Bonaduce *et al.*, 1976; Ciliberto & Pugliese, 1980).

A German research group under the guidance of Prof. Meischner (Göttingen) undertook sedimentological and geochemical studies (Fütterer, 1969; Paul, 1970; Meischner, 1973; Fütterer & Paul, 1976) as well as investigations of the taxonomy, ecology and seasonality of foraminifers and ostracods along the Istrian coast and Limski kanal N of Rovinj (von Daniels, 1970; Uffenorde, 1972, 1975). Palynological data were added by Beug (1977). For further descriptions of the ecological conditions, for example with sponge habitats in the area off the Istrian coast and Limski kanal, see Klöppel *et al*. (2011).

The Italian scientists mentioned above, as well as Sokač (1975) and Sokač & Hajek-Tadesse (1993) from the Croatian side, predominantly used the Van Veen grab sampler, whereas the equipment used by the Göttingen group was a high momentum gravity corer (core A18, Meischner & Rumohr, 1974), a box corer (core PO-1, "Kastenlot Kiel" Fütterer, 1969, for the position of both cores see text-fig. 1) and an improved Krumm bottom sampler (Limski kanal stations: von Daniels *et al.*, 1970). This equipment and the procedure for bringing the samples onboard seem to be of importance for the integrity of the microfaunal sample composition, whether they belong to a biocoenosis (living assemblage), a thanatocoenosis (death assemblage) or a palaeothanatocoenosis (death assemblage from a different climatic provinces = palaeothanatocoenosis I of Breman (1976) or from a different palaeoenvironmental depth zone due to the postglacial sea-level change = palaeothanatocoenosis II of Breman (1976)).

In connection with sampling cruises by Trotti (1969), Bonaduce *et al.* (1976) completed a huge study of Ostracoda, describing 46 new species and 2 new genera. Although all species are listed in Tab. 1 together with the latitudes and longitudes of their type localities, only the northernmost traverse from the Po delta towards the Mirna river/Istrian coast with the type localities of 6 new species from 34 m water depth or less are of special interest in the context of this publication (stations 2 to 5 of Bonaduce *et al.* (1976); refigured with *Cyprideis torosa* findings by Bonaduce *et al.* (2004)). These taxa of Bonaduce *et al.* (1976) are *Loxoconcha geometrica*, *Semicytherura rarecostata*, *Callistocythere folliculosa*, *Callistocythere gilva*, *Loxoconcha exagona* – together with the revised homonymous species *Leptocythere bituberculata* (= *Leptocythere istriana* Kempf, 2011).

All these ostracod taxa are based on descriptions of empty valves and therefore per se belong to the present-day thanatocoenosis. Nevertheless, they were interpreted as being part of the living inventory of the Adriatic Sea (Masoli, 1968; Bonaduce *et al.*, 1976; Bonaduce *et al.*, 2004). Since then, this attribution has been repeatedly published in summarizing checklists (Aiello *et al.*, 1995; Montenegro *et al.*, 1998; Aiello & Barra, 2010). Modern databases like "World Register of Marine Species" (WoRMS)/"World Ostracoda Database", "Encyclopedia of Life" (eol), North Atlantic Register for Marine Species (NARMS), "European Register of Marine Species" (ERMS)/MarBEF Data System" (marbef) and other zoological databases have followed this interpretation.

The attribution of these ostracods to the living fauna has to be questioned in view of sedimentary-geological studies which can be traced back to van Straaten (1970) and Fütterer & Paul (1976). Van Straaten (1970) emphasized that recent sands are restricted predominantly to a narrow coastal zone, and Pleistocene to Holocene residual sands were distributed widely on the shelf during the late glacial to post-glacial sea-level rise. Breman (1976) studied about 300 samples from the 360 stations visited by Van Straaten in 1962. In his tab. III d, he assigned the bottom sediments of the stations 134 to 138, which are relevant in this context, to the Pleistocene. In contrast to Bonaduce *et al.*

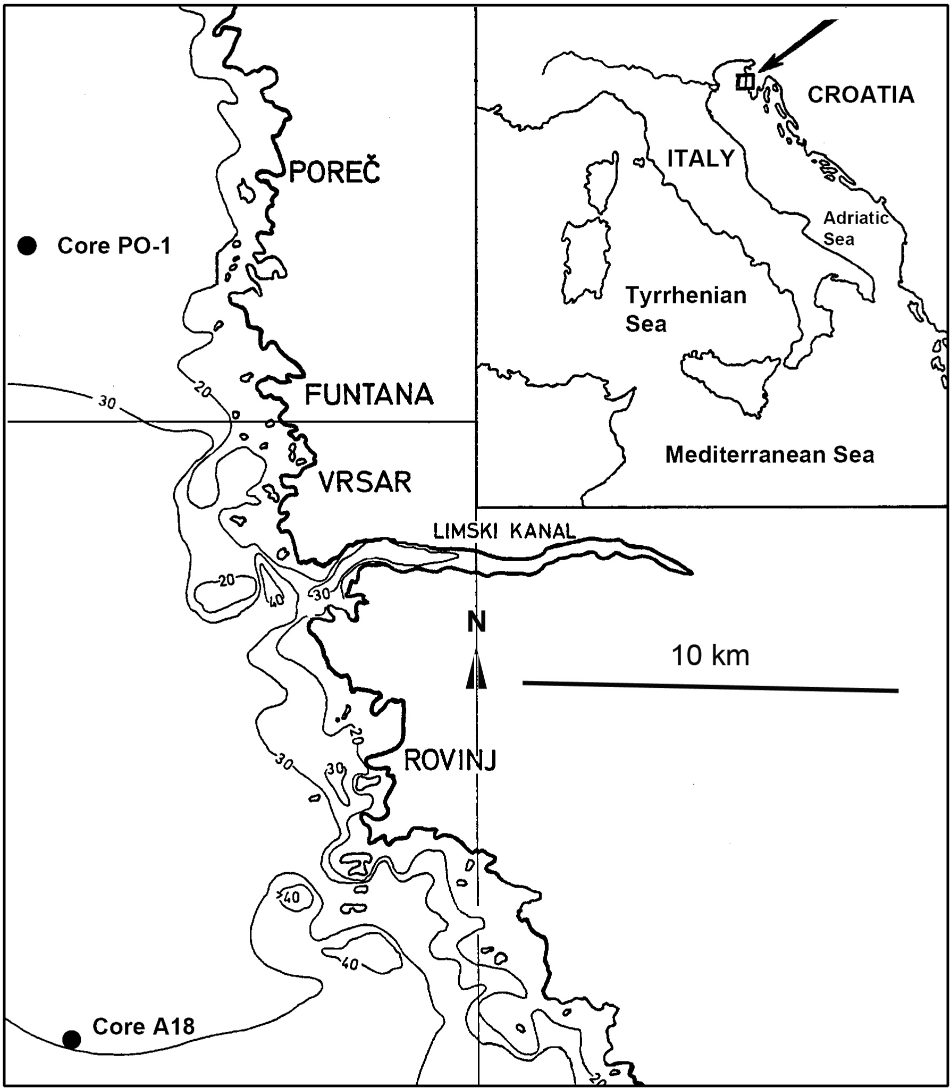

Fig. 1. Sketch map of the northeastern Adriatic Sea with the cores PO-1 and A18 offshore Istria, Croatia (modified, after Fütterer, 1969).

(2004), Breman (1976) found only in one station (station 136) of this area *Cyprideis torosa* (10 % of the counted valves), which clearly indicated to him that the sediment sample belongs to a palaeothanatocoenosis.

On the Istrian side of the Adriatic Sea, recent sedimentation is mainly confined to a 2 to 4 km wide zone (the "sediment zone I" of Fütterer & Paul (1976)). The underlying karst morphology causes a very patchy distribution of reworked "terra rossa" and skeletal debris. Further offshore, "sediment zone II" is a 2 km wide strip, which is still poorly sorted and free of Montmorillonite. "Sediment zone III", 5 to 15 km off the Is-

Tab. 1. Type localities of the new species described by Bonaduce *et al.* (1976). Latitude and longitude data after Trotti (1969), stations located in combination with hydrographical data. Digital version: OGA National Oceanographic Data Centre, Trieste.

Stations Bonaduce, Ciampo & Masoli [BCM], 1976 [No.]	Type locality of taxon	Latitude	Longitude	Depth [m below water surface]
2	*Loxoconcha geometrica* BCM, 1976	45° 3.00′ N	12° 48.00′ E	36
3	*Semicytherura rarecostata* BCM, 1976	45° 6.96′ N	13° 1.98′ E	32
4	*Callistocythere folliculosa* BCM, 1976	45° 9.96′ N	13° 12.96′ E	34
4	*Callistocythere gilva* BCM, 1976	45° 9.96′ N	13° 12.96′ E	34
5	*Leptocythere istriana* Kempf, 2011 (= *L.bituberculata* BCM, 1976), *Loxoconcha exagona* BCM, 1976	45° 13.98′ N	13° 21.96′ E	27
19	*Pontocypris acuta* BCM, 1976	43° 57.00′ N	14° 1.98′ E	71
20	*Microcythere vitrea* BCM, 1976	44° 3.96′ N	14° 12.96′ E	71
20	*Cytheromorpha nana* BCM, 1976	44° 3.96′ N	14° 12.96′ E	71
30	*Cytheropteron hadriaticum* BCM, 1976	43° 28.98′ N	15° 7.98′ E	125
30	*Loxoconcha bonaciamma* Kempf, 2011 (= *L. concentrica* BCM, 1976)	43° 28.98′ N	15° 7.98′ E	125
31	*Semicytherura stilifera* BCM, 1976	43° 34.98′ N	15° 16.98′ E	117
41	*?Cytheropteron infelix* BCM, 1976	42° 18.96′ N	14° 39.00′ E	71
44	*Argilloecia micra* BCM, 1976	42° 37.98′ N	15° 4.98′ E	180
44	*Cytheropteron garganicum* BCM, 1976	42° 37.98′ N	15° 4.98′ E	180
51	*Callistocythere vexata* BCM, 1976	43° 13.98′ N	15° 57.96′ E	113
69	*Buntonia textilis* BCM, 1976	42° 9.00′ N	16° 27.00′ E	133
69	*Paracytherois mediterranea* BCM, 1976	42° 9.00′ N	16° 27.00′ E	133
70	*Polycope truncatula* BCM, 1976	42° 13.98′ N	16° 34.98′ E	170
70	*Rectobuntonia miranda* BCM, 1976	42° 13.98′ N	16° 34.98′ E	170
70	*Eucythere pubera* BCM, 1976	42° 13.98′ N	16° 34.98′ E	170
70	*Parakrithe dimorpha* BCM, 1976	42° 13.98′ N	16° 34.98′ E	170
70	*Typhlocythere ruggierii* BCM, 1976	42° 13.98′ N	16° 34.98′ E	170
70	*„Bythoceratina“ reticulata* BCM, 1976	42° 13.98′ N	16° 34.98′ E	170
70	*Monoceratina oblita* BCM, 1976	42° 13.98′ N	16° 34.98′ E	170
70	*Loxoconchidea minima* BCM, 1976	42° 13.98′ N	16° 34.98′ E	170
70	*Cythropteron sulcatum* BCM, 1976	42° 13.98′ N	16° 34.98′ E	170
70	*?Cytheropteron tetrapteron* BCM, 1976	42° 13.98′ N	16° 34.98′ E	170
71	*Polycope parareticulata* BCM, 1976	42° 21.00′ N	16° 45.96′ E	210
71	*Polycopsis quadridentata* BCM, 1976	42° 21.00′ N	16° 45.96′ E	210
71	*Cytherella alvearium* BCM, 1976	42° 21.00′ N	16° 45.96′ E	210
71	*Cytheropteron zinzulusae* BCM, 1976	42° 21.00′ N	16° 45.96′ E	210
72	*Pedicythere phryne* BCM, 1976	42° 27.96′ N	16° 57.96′ E	212

74	*Polycope tholiformis* BCM, 1976	42° 30.96′ N	17° 1.98′ E	194
74	*Argilloecia robusta* BCM, 1976	42° 30.96′ N	17° 1.98′ E	194
78	*Cytheropteron monoceros* BCM, 1976	43° 31.98′ N	14° 18.00′ E	85
78	*Cytheropteron venustum* BCM, 1976	43° 31.98′ N	14° 18.00′ E	85
81	*Semicytherura robusta* BCM, 1976	43° 42.96′ N	14° 34.98′ E	79
100	*„Pedicythere“ tessellata* BCM, 1976	unknown		110

trian Coast, is uniformly better sorted (grain size maxima about 160 μ), although containing 70 to 80 % carbonate, like zone II. It belongs to the Montmorillonite clay mineral province, which is predominant in the Northern Adriatic Sea. The cores PO-1 and A18, the ostracods of which are discussed below, originate from zone III.

RESULTS

Ostracoda from core PO-1, WSW of Poreč/Istria

The 100 cm long core PO-1 (Fütterer, 1969; Fütterer & Paul, 1976; Beug, 1977) (position: 45°23′37′′N 13°00′31′′E, water depth: 28 m; Fig. 1) shows a subdivision into 4 units:

Unit D 0–5 cm: fine sand, few large mollusk shells

Unit C 5–20 cm: shell layer (*Ostrea edulis*, *Arca noae*, *Pecten* sp., *Cerithium rupestre*, *Murex* sp., det. Fütterer & Paul (1976)

Unit B 20–50 cm: transition to sandy silt

Unit A 50–100 cm: clayey silt, minor sand content, numerous vertical and horizontal burrows, mollusk shells rare.

Core PO-1 contains a relatively uniform ostracod assemblage, especially from 20 cm down to base (Tab. 2). Only the surface (0–3 cm) sample did not contain any *Cyprideis torosa*, while sample 5–10 cm and all deeper samples clearly indicate a palaeothanatocoenosis II. Uffenorde (in Fütterer & Paul, 1976: p. 16) found abundant *Cyprideis torosa* in sample 95–100 cm, assigning the source to "a neighbouring brackish water mass (lagoon?) or a wide zone of brackish water with a seaward overflow". Beug (1977) added that this finding is a further indication for an onlapping Adriatic Sea at about 7000–8000 a BP. Fütterer & Paul (1976) came to the conclusion that units A and B of the core might have their origin in a "shallow-water environment near to the coast … comparable with the present coastal zone between Grado and Venice". Recently, Dinelli *et al*. (2012) described a similar assemblage from the southern Po Plain as a lagoon facies association within a late glacial-early Holocene transgressive back-barrier succession. A sample from this lagoon facies association could be dated with the ^{14}C method as being from 7627 ± 172 cal. years BP (Dinelli *et al*. (2012: text-fig. 3).

Near the center of the Po Delta, this typical lagoon facies association has not been found, due to a different palaeoenvironmental development (Rossi, 2009). Transgressive barrier sands are overlain by marine inner shelf clays (ca. 5.,8 ka BP and younger), containing an ostracode assemblage dominated by *Pontocythere turbida* (G. W. Müller, 1894) and *Semicytherura acuticostata* (SARS, 1866) (assemblage 2 Rossi, 2009).

Cyprideis torosa is generally smooth, and adult nodose morphotypes occur very rarely, while the brackish-marine species *Leptocythere bacescoi* and *Loxoconcha stellifera* are confined to the lower part of the core.

Tab. 2. Ostracod distribution, ^{14}C and palynological data of core PO-1, WSW of Poreč/Istria. Light grey arrows towards left: shallow-marine species. Dark grey arrows towards right: brackish-lagoonal species.

Core PO-1 Core No.	1	3	5	7	9	11	13	15	16	17	19	Surface
Core depth [cm]	95-100	85-90	75-80	65-70	55-60	45-50	35-40	25-30	20-25	15-20	05-10	0-03
Ostracod taxa												
Aurila convexa (Baird, 1850)	X		X	X	X	X		X			X	X
Aurila ithacae Uliczny, 1969	X			X			X		X	X		
Neonesidea mediterranea (G. W. Müller, 1894)									X			
Callistocythere adriatica Masoli, 1968	X	?	X	X	X	X	X	X	X	X	X	X
Callistocythere littoralis (G. W. Müller, 1894)				X	X	X						X
Carinocythereis princeps (Terquem, 1878)	X											
Carinocythereis whitei (Baird, 1850)			X	X	X	X	X	X		X	X	X
Cyprideis torosa (Jones, 1850)	X	X	X	X	X	X	X	X	X	X	X	
Cyprideis torosa (Jones, 1850) (nodose morphotype)		X						X				
Cytheretta subradiosa (Roemer, 1838)	X				X			X	X	X	X	
Cytheridea neapolitana Kollmann, 1960	X	X	X	X	X	X	X	X	X	X	X	X
Cytherois uffenordei Ruggieri, 1975	X											
Cytherois sp.			X					X	X			
Cytheroma variabilis G. W. Müller, 1894								X				X
Cytheromorpha fuscata (Brady, 1869)			X			X	X					
Hemicytherura defiorei Ruggieri, 1953	X		X	X		X					X	X
Hemicytherura cf. *videns* (G. W. Müller, 1894)		X										
Hiltermannicythere turbida (G. W. Müller, 1894)	X	X	X	X	X	X	X	X	X	X	X	X
Hirschmannia sp.					X							
Leptocythere bacescoi (Rome, 1942)	X	X		X								
Leptocythere istriana Kempf, 2011						?						
Leptocythere ramosa (Rome, 1942)				X								
Leptocythere rara (G. W. Müller, 1894)	X				X	X					X	X
Leptocythere cf. *rara* (G. W. Müller, 1894)	X		X									
Leptocythere sp.	X											
Loxoconcha affinis (Brady, 1866)				X	X	X	X	X	X	X	X	X
Loxoconcha gibberosa Terquem, 1878								X				
Loxoconcha ovulata (O. G. Costa, 1853)	X	X	X	X	X	X	X	X	X	X	X	X
Loxoconcha rhomboidea (Fischer, 1855)	X	X	X									

Loxoconcha stellifera G. W. Müller, 1894	X	X	X		X	X						
Microcythere obliqua G. W. Müller, 1894								X				
Neocytherideis foveolata (Brady, 1870)	X											
Paracytheridea sp. A Uffenorde, 1972	X				X		X					
Paracytheridea triquetra (Reuss, 1850)	X			X	X	X	X	X	X	X	X	X
Paradoxostoma acuminatum G. W. Müller, 1894							X					
Paradoxostoma triste G. W. Müller, 1894								X	X			
Phlyctocythere sp.			X	X			X					
Pontocypris sp.	X				X						X	
Pontocythere turbida (G.W. Müller, 1894)	X	X	X	X	X	X	X	X	X	X	X	X
Propontocypris (Propontocypris) intermedia (Brady, 1868)		X							X			
Pseudopsammocythere similis (G. W. Müller, 1894)					X							
Pterygocythereis jonesii (Baird, 1850)	X	X	X	X	X	X	X	X	X	X	X	X
Sahnia fasciata (Brady & Robertson, 1874)				X	X		X		X		X	
Semicytherura acuta (G. W. Müller, 1912)	X	X										
Semicytherura acuticostata ventricosa (G. W. Müller, 1894)				X				X				
Semicytherura alifera Ruggieri, 1959			X	X	X	X	X		X			X
Semicytherura diafora Barbeito-Gonzalez, 1971		X		X	X	X	X				X	X
Semicytherura dispar (G. W. Müller, 1894)				X								
Semicytherura incongruens (G. W. Müller, 1894)	X	X	X	X	X	X	X	X	X	X	X	X
Semicytherura inversa (Seguenza, 1880)								X	X		X	X
Semicytherura quadridentata (Hartmann, 1953)									X			
Semicytherura rara (G. W. Müller, 1894)		X	X	X		X		X	X		X	
Semicytherura rarecostata Bonaduce, Ciampo & Masoli, 1976 s.l.	X		X	X	X	X	X	X	X		X	X
Semicytherura sulcata (G. W. Müller, 1894)	X				X							
Semicytherura cf. *tergestina* (cf. Uffenorde, 1972)							X		X		X	X
Xestoleberis communis G. W. Müller, 1894		X	X	X	X	X	X	X	X	X	X	X
Xestoleberis spp.	X	X	X	X	X	X	X	X	X		X	X
^{14}C dating (Fütterer & Paul, 1976)									18 cm below surface: 6640±120 BP			
Pollen analysis (Beug, 1977)	*Quercus robur* dominant; *Corylus* high values at the base: reducing/*Picea* & *Abies* increasing towards core no. 16; *Fagus* & *Alnus* rel. frequent; *Hedera* continuously present; *Ulmus* strongly varying									cores no. 17, 19 & surface sample: no analysis possible		
Interpretation (acc. Schmidt et al., 2001)	Pollen Zone/Subzone: 5/2											
Period	Atlantic											

Shallow marine species, present in the majority of samples, are:

Aurila convexa, Callistocythere adriatica, Carinocythereis whitei, Cytheridea neapolitana, Hiltermannicythere turbida, Loxoconcha affinis, Loxoconcha ovulata, Paracytheridea triquetra, Pontocythere turbida, Pterygocythereis jonesii, Semicytherura alifera, S. incongruens and S. rarecostata as well as xestoleberidids.

This rich, homogeneous ostracod palaeothanatocoenosis is certainly older than the shell layer of unit C with an oyster shell indicating a ^{14}C age of 6640 ± 120 a BP, which can be assigned to the Atlantic period or the Holocene climatic optimum.

In connection with a sea-level curve for the northern Adriatic Sea elaborated by Lambeck *et al.* (2004), the range of the calculated sea-level at 6.6 ka BP is about –4 to –8 meters below the present sea-level just at the end of the extreme postglacial sea-level rise.

It is remarkable that this ^{14}C age is just at the breaking point between a rapid sea-level rise of 90–100 cm/100 years (represented by the clayey and sandy silt in units A and B of core PO-1) and a much slower rise of 9–14 cm/100 years in the fine sand in unit D.

The sediments in the units C and D are interpreted as lag deposits, typical of the sediment-starved North Adriatic shelf (Correggiari *et al.*, 1996). The Highstand Systems Tract (HST) in the last 5 ka BP especially yields more phases of non-deposition than deposition and these latter are concentrated in the western part of the Adriatic Sea (Po delta and adjacent lobes Correggiari *et al.*, 2005).

Ostracoda from core A18 SW of Rovinj/Istria

The core A18 SW of Rovinj/Istria (Fütterer, 1969; Fütterer & Paul, 1976) (position: 45°0’49’’N, 13°33’23’’E, water depth: 34 m; Fig. 1) has an overall ostracod assemblage similar to that found in core PO-1 (Tab. 3, samples between 5 and 50 cm).

The core sample from the uppermost 5 cm shows an impoverished fauna with smooth *Cyprideis torosa* as well as its nodose morphotypes, *Leptocythere bacescoi*, *Loxoconcha stelligera* and *Semicytherura sulcata*. This fauna also indicates palaeothanatocoenosis II in a nearshore, even more brackish environment. Although there was no special comment by Fütterer & Paul (1976), it is assumed that this break in the ostracod record was caused by a burrow bioturbation bringing material from strata deeper than those cored near to the surface.

Ostracoda from a grab sample from position A18 SW of Rovinj/Istria

In contrast to this result, the uppermost 3 cm from the same station (position: 45°0’49’’N, 13°33’23’’E, water depth: 34 m), taken by a Van Veen grab, display a quite different faunal spectrum (Tab. 4). The rich and diverse ostracod assemblage contains *Cytherois frequens* as part of the biocoenosis (with soft parts and stained with rose bengal). In addition to further specimens of this species without soft parts, *Paracytherois flexuosa, Paradostoma simile, Pontocypris acuminata, Xestoleberis communis* and other xestoleberidids are part of the thanatocoensosis. All these taxa are thin-shelled. Moreover, the sample is characterized by abundant stained Bryozoa. Also remarkable is the absence of *Carinocythereis whitei*, *Cytheretta subradiosa*, *Hemicytherura defiorei*, *Hiltermannicythere turbida*, *Leptocythere rara*, *Pontocythere turbida*, *Pterygocythereis jonesii*, and *Semicytherura incongruens*, *S. inversa* and *S. rarecostata* s. l.

Although no further investigations were undertaken by Fütterer & Paul (1976) or by the author, the recent fauna seems to belong to the “Biocoenosis of detritic bottoms of the open Adriatic Sea” (Gamulin-Brida, 1974, UNEP/MAP, 2015).

Tab. 3. Ostracoda from core A18, SW of Rovinj/Istria. Light grey arrows towards left: shallow-marine species. Dark grey arrows towards right and rectangles: brackish-lagoonal species.

Core A18 Core No.	10	9	8	7	6	5	4	3	2	1
Core depth [cm]	45-50	40-45	35-40	30-35	25-30	20-25	15-20	10-15	05-10	00-05
Ostracod taxa										
Aurila convexa (Baird, 1850)			X		X		X		X	X
Aurila ithacae Uliczny, 1969	X		X		X		X		X	
Callistocythere adriatica Masoli, 1968	X		X		X		X		X	
Carinocythereis princeps (Terquem, 1878)	X									
Carinocythereis whitei (Baird, 1850)			X				X		X	
Cyprideis torosa (Jones, 1850)	X		X		X		X		X	X
Cyprideis torosa (Jones, 1850), nodose morphotype	X									X
Cytheretta subradiosa (Roemer, 1838)	X		X		X		X		X	
Cytheridea neapolitana Kollmann, 1960										X
Cytherois uffenordei Ruggieri, 1975										X
Cytheroma sp.					X					
Hemicytherura defiorei Ruggieri, 1953	X		X		X		X		X	
Hiltermannicythere turbida (G. W. Müller, 1894)			X		X		X		X	X
Leptocythere bacescoi (Rome, 1942)										X
Leptocythere cf. *rara* (G. W. Mueller, 1894)	X									
Leptocythere lagunae Hartmann, 1958 (juv.)	X									
Leptocythere ramosa (Rome, 1942)									X	
Leptocythere rara (G. W. Mueller, 1894)			X		X				X	X
Loxoconcha ovulata (O. G. Costa, 1853)	X		X		X				X	
Loxoconcha rhomboidea (Fischer, 1855)	X		X		X		X		X	
Loxoconcha stellifera G. W. Müller, 1894										X
Microcytherura angulosa (Seguenza, 1880)	X				X					
Neocytherideis foveolata (Brady, 1870)	X									
Paracytheridea sp. A Uffenorde, 1972	X		X		X					
Paracytheridea triquetra (Reuss, 1850)	X						X		X	
Pontocypris sp.										X
Pontocythere turbida (G.W. Müller, 1894)	X		X		X		X		X	
Pseudocythere calcarata (Seguenza, 1880)			X				X		X	
Pterygocythereis jonesii (Baird, 1850)	X		X		?		X		X	
Semicytherura acuta (G. W. Müller, 1912)	X						X		X	
Semicytherura acuticostata ventricosa (G. W. Müller, 1894)			X						X	

Semicytherura cf. *tergestina* (cf. Uffenorde, 1972)							X		X	
Semicytherura diafora Barbeito-Gonzalez, 1971					X					
Semicytherura incongruens (G. W. Müller, 1894)	X		X		X		X		X	
Semicytherura inversa (Seguenza, 1880)	X		X		X		X		X	
Semicytherura rara (G. W. Mueller, 1894)							X		X	
Semicytherura rarecostata Bonaduce, Ciampo & Masoli, 1976 s.l.	X		X		X		X		X	X
Semicytherura sulcata (G. W. Müller, 1894)										X
Xestoleberis communis G. W. Müller, 1894			X		X		X		X	
Xestoleberis spp.	X		X		X		X		X	

However, a further component could be proven for the first time in sediments of offshore Istria. This is a group of species indicating warmer water. Four species can be included in this group: *Cytherelloidea beckmanni*, *Triebelina raripila*, *Aurila interpretis* and *Hemicytherura gracilicosta*. These are representatives of the palaeothanatocoenosis I in the sense of Breman (1976) with species which come from a southern climatic province via the northwards, anti-clockwise directed East Adriatic Currents (EAC, UNEP/MAP, 2015). *Cytherelloidea beckmanni* has been proven as strong climatological indicator (Barra, 1997). Melis & Pugliese (1985) found *Cytherelloidea beckmanni* together with *Hemicytherura gracilicosta* in association with *Posidonia oceanica* (? Meadows or banks of dead leaves of *Posidonia oceanica*) west of Sicily. Bonaduce *et al*. (1976) interpreted *Aurila interpretis* as characteristic of the Levant Basin. They found this species only once frequently (SSE Italy between Lecce and San Maria di Leuca, near-shore by diving). The frequent occurrence of *Aurila interpretis* at a single station E of Venice, reported by Breman (1976, tab. III d), seems to be due to reworking (so-called Pleistocene age sediment). Barra (1997) mentioned *Triebelina raripila* as a species that prefers the southern part of the Mediterranean Sea, but may have scattered occurrences further north. This occurrence is here interpreted as influenced by currents like the EAC mentioned above.

DISCUSSION

As exemplified by the two cores PO-1 and A18 drilled offshore from the Istrian Peninsula (Croatia), the northern Adriatic Sea bottom shows a very complicated composition connected with the postglacial sedimentation and re-deposition. The denudation of sediments deposited in the late glacial/postglacial Transgressive Systems Tract, lag deposition during the Maximum Flooding Surface and the Highstand Systems Tract play an important role in the actual sediment pattern. It has to be borne in mind that many of the shells found at the Adriatic Sea bottom are in fact fossils. This could be proven in the present study by ostracods.

The very sandy pelite community (stations 2–4) and the fine sand community (station 5) described by Bonaduce *et al*. (1976) are not genuine recent or subrecent death assemblages. They are predominantly palaeothanatocoenoses with different palaeoenvironmental depth zones due to the postglacial sea-level change (palaeothanatocoenoses II of Breman (1976)). The widespread Pleistocene of the northern Adriatic Sea postulated by Breman (1976) could not be reached, either in the stations sampled by Bonaduce et al. (1976), or by Fütterer & Paul (1976) or the present study.

Tab. 4. Ostracoda from a Van Veen grab sample from position A18, SW of Rovinj/Istria.

Station A18 (Van Veen grab) [cm below surface]	00-ca.03
Ostracod taxa	
Aurila convexa (Baird, 1850)	X
Aurila interpretis Uliczny, 1969	X
Aurila ithacae Uliczny, 1969	X
Bairdia spp.	X
Callistocythere adriatica Masoli, 1968	X
Callistocythere littoralis (G. W. Mueller, 1894)	X
Callistocythere lobiancoi (G. W. Mueller, 1894)	X
Cytherelloidea beckmanni Barbeito-Gonzalez, 1971	X
Cytherois frequens G. W. Mueller, 1894	X
Hemicytherura gracilicosta (Ruggieri, 1953)	X
Jugosocythereis prava (Baird, 1850)	X
Loxoconcha affinis (Brady, 1866)	X
Loxoconcha ovulata (O. G. Costa, 1853)	X
Loxoconcha rhomboidea (Fischer, 1855)	X
Microcytherura angulosa (Seguenza, 1880)	X
Neonesidea longevaginata (G. W. Mueller, 1894)	X
Paracytheridea sp. A Uffenorde, 1972	X
Paracytheridea triquetra (Reuss, 1850)	X
Paracytherois flexuosa (Brady, 1867)	X
Paradoxostoma simile G. W. Mueller, 1894	X
Pontocypris acuminata G. W. Müller, 1894	X
Semicytherura acuticostata ventricosa (G. W. Mueller, 1894)	X
Semicytherura alifera Ruggieri, 1959	X
Triebelina raripila (G. W. Mueller, 1894)	X
Urocythereis sp. juv.	X
Xestoleberis communis G. W. Mueller, 1894	X
Xestoleberis spp.	X

Many of the new species created by Bonaduce *et al*. (1976) are not actually living. Their inclusion into zoological databases like World Register of Marine Species (WoRMS), World Ostracoda Database, Encyclopedia of Life (eol), European Register of Marine Species (ERMS) and other zoological databases should be marked as Quaternary.

Quite a number of northern Adriatic Sea Ostracoda have been attributed to recent habitats – based only on the study of empty valves or carapaces. In view of sedimentological studies which can be traced back to van Straaten (1970) and Fütterer & Paul (1976) this assumption has to be questioned.

Information is given here on the Holocene lagoonal to marine ostracod succession from the cores PO-1, SW of Poreč and A18, SW of Rovinj (both of offshore Istria, Croatia), which was taken by Fütterer (1969). Both cores show a relatively uniform ostracod assemblage 5 cm and deeper below sediment surface, which clearly indicates a death assemblage from a different palaeoenvironmental depth zone due to the postglacial sea-level change (palaeothanatocoenosis II). In the uppermost 3–5 cm, the ostracod composition is extremely different from sample to sample, depending on bioturbation, storm re-deposition or lag deposition.

At station A18, storm deposits (abundance of Bryozoa) with a mixture of biocoenotic, thanatocoenotic and palaeothanatocoenotic ostracods were recorded for the first time in the northeastern Adriatic Sea. The latter group of ostracods belongs to a death assemblage derived from the southern Adriatic or other parts of the Mediterranean Sea (palaeothanatocoenosis I).

Taking samples for 'living' Ostracoda requires the use of appropriate sampling devices like high momentum gravity corer and Krumm bottom sampler, the optimum in gathering of a sediment sample without, or with as little as possible, turbulence on the bottom, retrieving the grab sampler with the least possible undulation of the sea and ladling the surface of the sample onboard.

Although only a few studies have dealt with the eastern part of the Northern Adriatic Sea, it is clear that wide areas of the sea floor are covered generally by reworked lag deposits, which were created in connection with the Early Holocene marine transgressions (Transgressive Systems Tract about 9–7 ka BP) and the Holocene climatic optimum (Maximum Flooding Surface/Condensed Interval about 6–5 ka BP, Corregiari *et al*., 2005). The transgressive surface beneath these lag deposits seems to be much older, probably 12–14 ka BP (Dinelli *et al*. (2012).

The attribution of 46 new species, erected by Bonaduce *et al*.(1976), to the recent fauna of the Adriatic Sea in the "World Register of Marine Species" (WoRMS)/ "World Ostracoda Database", "Encyclopedia of Life" (eol), North Atlantic Register for Marine Species (NARMS), "European Register of Marine Species" (ERMS)/MarBEF Data System" (marbef) and other zoological databases should – at least partially – be used with caution.

Moreover, no information concerning the position of the type localities of these new taxa was given by Bonaduce *et al*. (1976). For the first time, latitude/longitude data can be reconstructed and presented here (with the help of the OGA National Oceanographic Data Centre, Trieste).

It is proposed that the inclusion of these taxa into general zoological data bases should be marked as Quaternary in order to distinguish them from living ostracods.

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